REPORT OF

Comparative Tests of Roundels

FROM AN

Opthalmologist's Standpoint.

NELSON MILES BLACK, M.D.

PRELIMINARY REPORT OF COMPARATIVE TESTS OF ROUNDELS, FROM AN OPHTHALMOLOGIST'S STANDPOINT.

NELSON MILES BLACK, M.D., MILWAUKEE, WIS.

Something over 5,000 miles were covered by the writer in the cab of an engine for the purpose of obtaining data concerning the visual requirements of enginemen; these observations were made over many different roads, at all times of day and night, and in all kinds of weather. As a result, it was observed that there were several other factors to be taken into consideration besides good vision, such as conditions existing about an engine and in the atmospheric interference with the visibility of signals, the location of signals against bad backgrounds, the proximity to buildings, and bad foreground, the care taken of the lamps and roundels in semaphore spectacle frames. These were considered in a former paper, but no reference was made to some very important features, such as the lamps, the lenses, and colored glass used, and in going over a considerable portion of a road the difference in the intensities of the colored signals was very noticeable this could not be wholly accounted for by the personal equation in taking care of the lamps. Inquiry of the signal engineers as to the methods of selecting the colored roundels cleared this up to a certain extent. By holding the glass toward the light (usually daylight) and comparing them with a minimum and maximum standard adopted by the road, the intensity of the new flats selected must come between the two. It is an utter impossibility for the eye after a few minutes' work of this kind to appreciate the difference between even marked degrees of intensity, as the color perceiving portions of the retina become incapable of differentiating, by over-exposure to the same sensation.

The essential feature of a night signal is light, and it is a well-known fact that any interposed media interferes with its intensity, by reflection, diffraction and refraction. Even with a pure white lens the polished surface reflects back a certain percentage of the light, so if the original light be represented by 100, the amount of light projected would be 95 per cent. or 97 per cent. of the original, and this intensity is again reduced by the reflection of the roundel in the semaphore frame, and the colored glass absorbs still more of the original projected light; also the thickness of the glass interferes somewhat.

In a colored night signal, the one that gives the greatest intensity of color at the greatest distance most nearly approaches the ideal. It goes without saying that a white light would be the best for a danger indication, as it can be seen at the greatest distance, but red having been used for a danger signal so long it is almost synonomous with it, and to change would be out of the question, again all lights for illuminating being white makes it impossible to be used for this purpose.

We must work along two lines to get the best results with colored signals, i. e., one line represents greatest intensity of color; the other the greatest distance at which the color can be distinguished, the point at which these two lines intersect will give the nearest approach to perfection with the methods of signaling now in use. The requisites for this result are, first, a good source of illumination; this requires a good lamp, good oil, a good burner with a properly trimmed wick, and a lamp which will allow of a steady, clear flame; secondly, the lamp must be equipped with a good condensing lens, adjusted at the proper focal distance; thirdly, the roundel should be of such composition as to allow the greatest passage of light, impregnated with the given color, that can be seen at the greatest distance. In order to accomplish this, a certain amount of yellow must be combined with the red and green, or, in other words, the spectrum color started with as a standard must be diluted with yellow sufficiently to allow of the passage of a greater percentage of light, and that combination of yellow and red or green which gives the best color at the greatest distance is the safest for use as a signal. The thickness of the glass makes some difference, but it must be thick enough to resist certain atmospheric conditions and the expansion and contraction of the semaphore spectacle frame. The surface must be smooth, as the dust, dirt, soot, mist and snow will cling more to a rough or irregular surface, to say nothing of refraction and diffraction of light by the uneven surface.

The sweating of the condensing lens in the lamp is a feature to be avoided. Great difficulty was encountered when first making the comparison tests by using old-fashioned switch lamps, as the lenses were so coated with condensed moisture as to very much reduce the intensity of the light.

The points above referred to are undoubtedly A B C part of signal work to you all, but I wish to refer to them so that if any factor in the tests has been omitted, attention may be called to it, and in the future may be avoided or improvement made by correction of some feature.

Standard roundels were obtained from different roads and from different manufacturers, and in this report no mention of maker's name will be made, but will be designated by X., Y., Z. and O., as in the complete report the photometric and spectro photometric value will be given, the time being too short to obtain these for this meeting.

The first series of tests consisted of picking from each set of samples the lenses that gave the best color at the greatest distance. Five of the Adams & Westlake Company standard semaphore lamps, with non-sweating ventilation, were used. These were fitted with condensing lenses of latest approved pattern; each was measured to insure that the lenses all had the same focal distance. The lamps were fitted with same burners and wicks, with flame in same horizontal plane as lens. Headlight oil which flashed at 110 degrees was used, an attachment was made, fitted to the collar fastening the lens to the lamp, for

holding the roundels; a sheet-iron diaphragm with a hole 8.7 mm. in diameter at the optical center of the lens was used to cut down the size of the light, as a tangent sufficiently long to get the vanishing point of the full size lens could not be found in the neighborhood. With this apparatus and the best of each set of samples selected, the following tests were made:

First, the comparative distance at which the reflection of the color disappeared, when projected on a sheet of white glazed bristol board. This test was conducted in-doors.

TEST NO. 1.

Reds Best	X2
Reds 2d Best	Y1
Reds 3d Best	X1
Reds 4th Best	Y2
Reds 5th Best	Z1
Greens Best	Z1
Greens 2d Best	X1
Greens 3d Best	X2
Greens 4th Best	O1
Greens 5th Best	Y1
Yellow Best	X1
Yellow 2d Best	Z1
Yellow 3d Best	Y1
Yellow 4th Best	X2
Yellow 5th Best	Y2

TEST NO. 2.

The determination at 2,000 ft., which roundel gave the best color:

Reds Best	X1
Reds 2d Best	X2
Reds 3d Best	Y1
Reds 4th Best	Y2
Reds 5th Best	Z1
Greens Best	X1
Greens 2d Best	X2
Greens 3d Best	Y1
Greens 4th Best	O1
Greens 5th Best	Z1
Yellows Best	Z1 X2
Yellows 2d Best	X1
Yellows 3d Best	Y1 Y2

TEST NO. 3.

By observing the red roundels through green spectacles a certain percentage of the pure red is neutralized, green being the complimentary color of red, and at a certain distance, varying with the amount of red in the glass, the light will be lost.

By using red spectacles with the green roundels the same effect is produced. This will give the disappearing distance at a shorter range.

Reds Best	X1
Reds 2d Best	X2
Reds 3d Best	Y1
Reds 4th Best	Y2
Reds 5th Best	Z1
Greens Best	X1
Greens 2d Best	X2
Greens 3d Best	Y1
Greens 4th Best	Y2
Greens 5th Best	Z1

YELLOW was not used with the test.

TEST NO. 4.

The same test as No. 3 was made, cutting down the pencil of light to 8.7 mm.

Reds Z1 lost 192 ft.
Reds Y2 lost 242 ft.
Reds Y1 lost 342 ft.
Reds X2 lost 352 ft.
Reds X1 lost 502 ft.
Greens Z1 lost 70 ft.
Greens Y1 lost 125 ft.
Greens O1 lost 220 ft.
Greens X2 lost 280 ft.
Greens X1 lost 305 ft.

The tests with the yellow lenses, when compared with a white light at a distance, were disappointing, as it was hard to determine which was yellow, there being merely a diminished intensity with the lamps having the yellow roundels before them, which demonstrated that the admixture of yellow with the red and green is not a disadvantage.

Each of these tests were made on four different evenings with four different sets of observers consisting of from two to five persons, and the records kept showed an unanimous decision as here indicated, of course, personal equation taken into consideration, there was some variation in the distances at which the various lights vanished and appeared, but the herewith appended report gives the average.

At the next meeting, if such is your wish, I should be pleased to give the full report, together with a demonstration with the lamps, roundels and colored spectacles, etc.

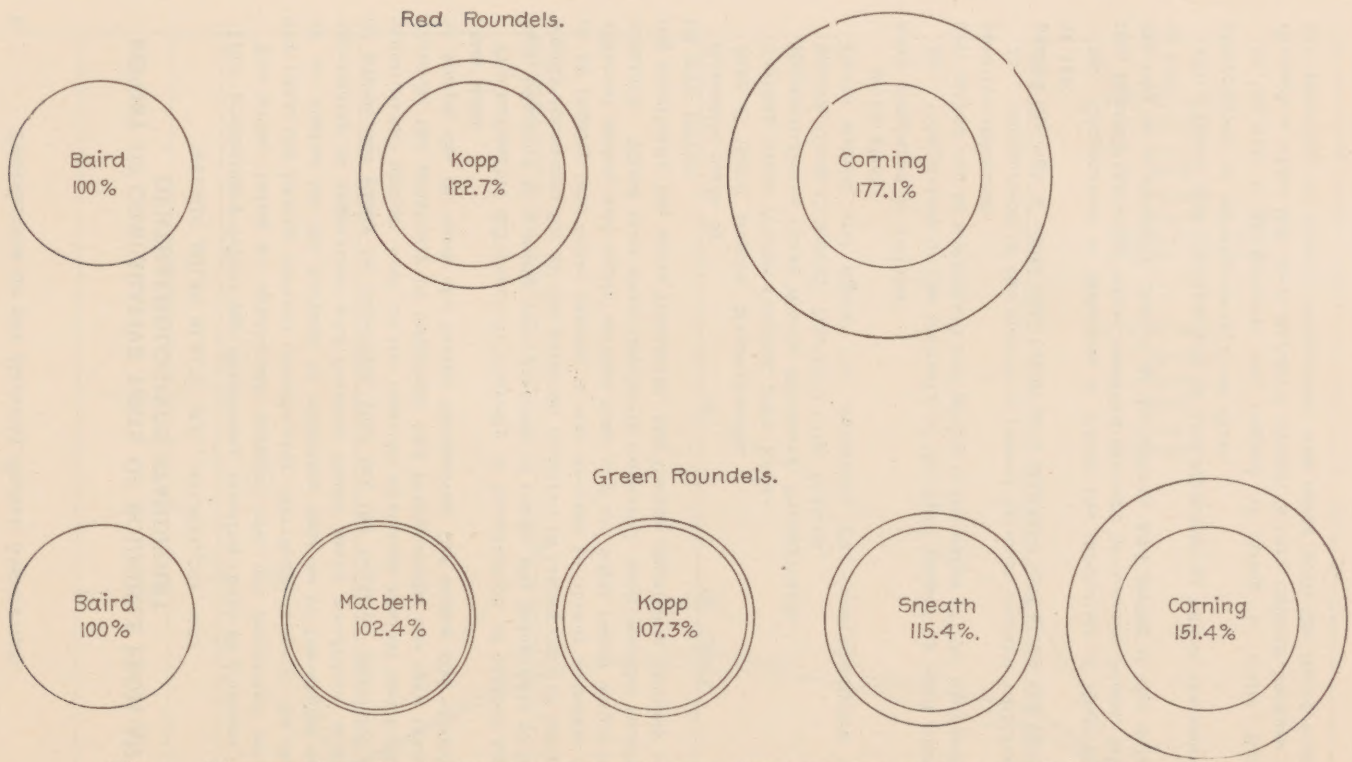

Fig. 1. Diagram of results obtained in photometric test; Baird roundels used as standard of comparison and given value of 100 per cent.

REPORT OF COMPARATIVE TESTS OF ROUNDELS FROM AN OPHTHALMOLOGIST'S STANDPOINT.

NELSON MILES BLACK, M.D., MILWAUKEF, WIS.

[For preliminary report see September meeting, held at Chicago.]

The writer being an ophthalmic surgeon and not connected with any road, but having covered considerably over 5,000 miles in the cab of an engine for the purpose of collecting data as to the visual requirements of enginemen and firemen, found many conditions, some of which can easily be remedied, that tax the required standard of vision to the utmost, such as the location of signals against bad backgrounds, the proximity to buildings, bad foregrounds, the care taken of lamps, the oil used, the lamps themselves, the lenses and colored glass used.

The noticeable difference in intensity of illumination of colored signals, observed in passing over portions of roads, not being able to be wholly accounted for by the personal equation in taking care of lamps or by inquiry into other causes, it was decided to obtain roundels of different makes and apply various tests and see what result would be obtained. These tests were absolutely impartial, each roundel receiving identically the same treatment, the results depending entirely on its own merits.

Roundels made by

John C. Baird, Boston, Massachusetts.

Corning Glass Works, Corning, New York.

Macbeth-Evans Glass Works, Pittsburg, Pennsylvania.

Sneath Glass Company, Hartford City, Indiana.

Union Switch and Signal Co., Swissvale, Pa., (manufacturers of Kopp glass).

were compared as follows:

1st. Comparison of the intensity of the light passed by each roundel; taking one as a standard and giving it the value of 100, also comparative thickness.

2d. Comparison of the spectrum passed by each roundel with that passed through a white lens taken as a standard and given the value of 100.

3d. Comparison of distances at which the intensities of illumination became the same when observed through bi-concave lenses, taking one as a standard, placed at 10 metres, and giving it the value of 100.

4th. Track test—comparison of the distances at which the colors disappeared on moving away from them.

In the first or photometric test, instead of using a white light through a white lens as a standard (which is very difficult because of the difference in color), comparison was made with the Baird roun-

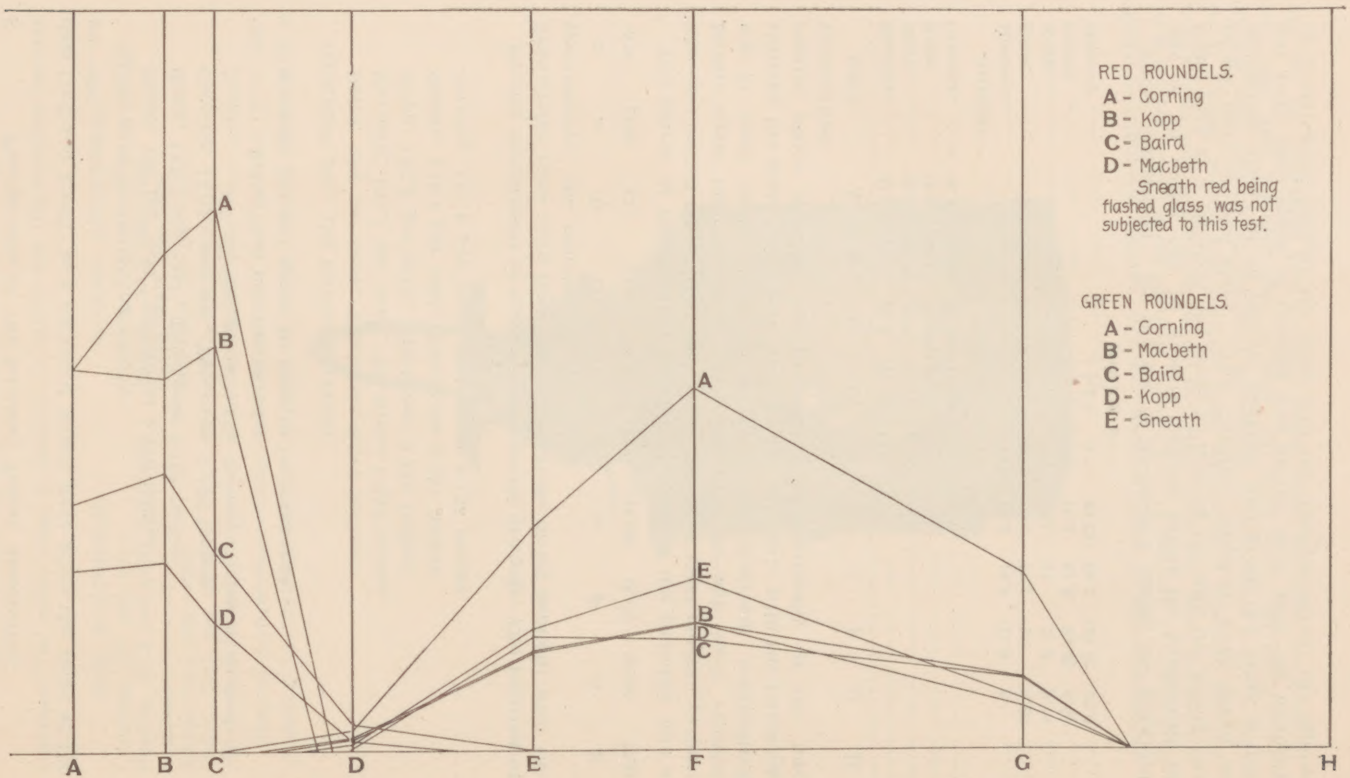

Fig. 2. Diagram showing curves of color value in spectro-photometric test.

dels (red and green) as a standard, which were given the value of 100 per cent.

REDS gave the following results:

Baird, 100 per cent., Thickness 0.270 inches.
Kopp, 122.7 per cent., Thickness 0.153 inches.
Corning, 177.1 per cent., Thickness 0.296 inches.
Sneath, ————, Thickness 0.328 inches. Being a flashed. color, was not compared.
Macbeth did not arrive in time to be compared.

GREENS gave the following results:

Baird, 100 per cent., Thickness 0.240 inches.
Macbeth, 102.4 per cent., Thickness 0.253 inches.
Kopp, 107.3 per cent., Thickness 0.259 inches.
Sneath, 115.4 per cent., Thickness 0.259 inches.
Corning, 151.4 per cent., Thickness 0.228 inches.

(See Fig. 1.)

Second comparison or spectro photometric analysis: The location of Fraunhofer lines were first determined from direct sunlight with the spectroscope, and resulted as follows:

A	a	B	C	D	E	b	F	G	H
0.75	1.162	3.34	4.104	8.99	13.182	14.188	18.172	35.105	37.34

The source of illumination for this analysis of the roundels was a kerosene switch lamp fitted with white lenses of most modern pattern having equal foci; the spectrum transmitted through each roundel was in every instance compared with the spectrum transmitted through the same white lens taken as 100 per cent., with the following results, which represent the percentage of luminosity of the hue transmitted.

REDS	A	a	B	C	D	E	b	F	G	H
Macbeth..........	24.6	28.4	25.6	17.45	1.7	....	....	....	....	....
Baird................	33.5	34.25	37.6	26.85	8.55	....	....	....	....	....
Kopp...............	51.6	50.1	50.15	54.7	....	....	....	....	....	....
Corning..........	51.4	67.35	67.35	73.1	....	....	....	....	....	....
GREENS										
Macbeth..........	....	....	....	....	1.6	13.2	14.9	17.3	6.	....
Baird	....	....	....	....	0.2	15.4	17.1	15.	9.65	....
Kopp...............	....	....	....	....	1.8	13.5	14.	17.2	9.75	....
Sneath	....	....	....	....	0.95	16.5	21.2	23.05	6.93	....
Corning	....	....	....	0.1	2.75	30.25	38.7	48.75	23.6	....

(See Fig. 2.)

Third comparison: By the use of bi-concave lenses, the apparent size of an object can be greatly reduced, giving the appearance of being seen at a distance, the same as looking through the wrong end of an opera or field glass. The Corning roundels were taken as standards, placed at 10 meters' distance, and given the value of 100 per cent; each make of roundel was moved back until the intensity of illumination became the same and the distance noted; the figures

represent the percentage of distance at which the illumination became equal:

RED ROUNDELS.	GREEN ROUNDELS.
Corning, 100 per cent.	Corning, 100 per cent.
Sneath, 87.2 per cent. (flashed glass).	Sneath, 92.8 per cent.
Kopp, 75.7 per cent.	Baird, 69.4 per cent.
Baird, 54.7 per cent.	Macbeth, 67 per cent.
Macbeth, 42.2 per cent.	Kopp, 66 per cent.
	(See top half Fig. 4.)

Fourth comparison—track test: An Adams & Westlake Co.'s non-sweating ventilation, standard semaphore lamp (Fig. 3), fitted with a

Fig. 3.

condensing lens of latest improved pattern, burning headlight oil which flashed at 110 degrees F., and having plane of flame parallel to plane of condensing lens, was used. This was placed between double tracks on a support opposite a mile-post; each roundel was placed before it in turn. Five observers on hand-cars (besides the crews) were moved away from the lamp until the color of each roundel was lost, the number of telegraph poles being counted and averaging 35 to the

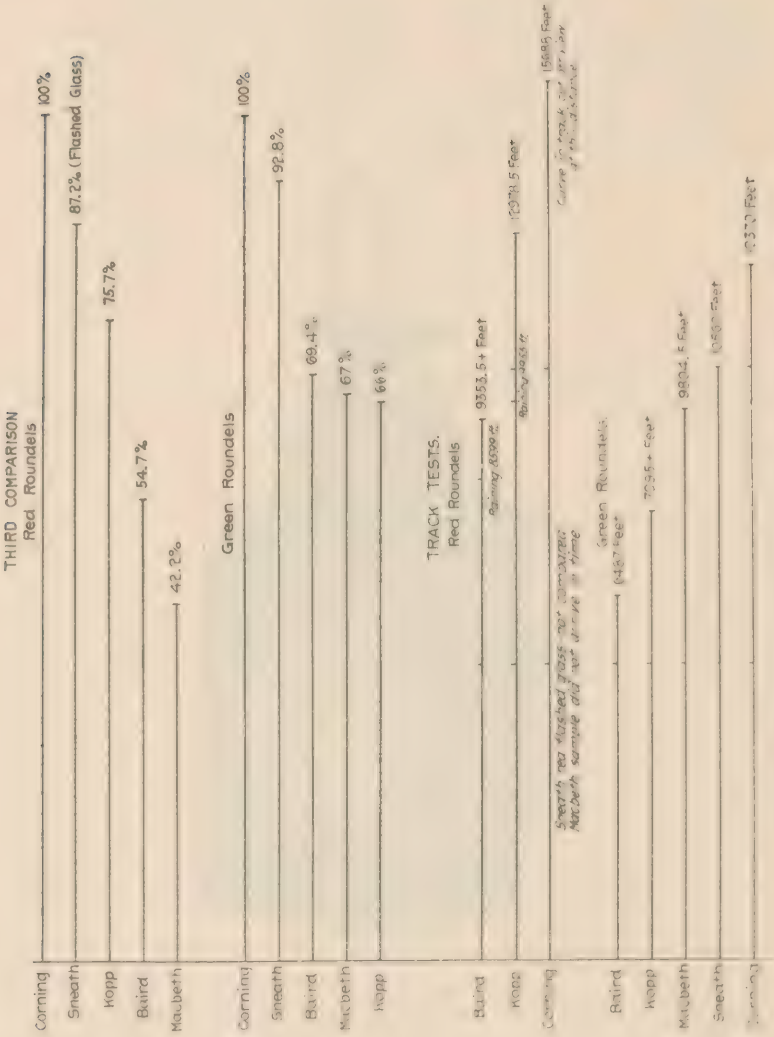

Fig. 4. Diagrams of bi-concave lens test and track test.

mile, or 150.85 feet between poles. It was raining quite hard at the beginning of this test, with the following results:

REDS. COLOR LOST.
Baird, 1 mile, 22 poles—8,599 feet.
Kopp, 1 mile, 31 poles—9,955 feet.
Corning, 2 miles, 34 poles—15,688 feet.

On account of turn in road it was impossible to obtain distance at which color the Corning roundel was lost.

On going back, it having stopped raining, Kopp red was picked up at 2 miles 16 poles—12,978½ feet; Baird red at 1 mile 29 poles—9,353½ feet. The Sneath red, being flashed glass, was not compared, and the Macbeth red did not arrive in time for this test.

It had cleared off by the time the greens were tried and the moon was shining. Result:

Baird, 1 mile, 8 poles—6,487 feet.
Kopp, 1 mile, 18 poles—7,995 feet.
Macbeth, 1 mile, 30 poles—9,804½ feet.
Sneath, 2 miles—10,560 feet.
Corning, 2 miles, 12 poles—12,370 feet.

(See bottom half Fig. 4.)

The various tests were not carried through with the yellow roundels. With the track test it was almost impossible at two miles' distance to distinguish between the light coming through a white lens and that through the same lens with a yellow roundel before it unless such roundel were very dark and the color composed of a great deal of orange and red. Such a light cannot be seen at as great a distance and is very apt to be mistaken for a red or danger signal. It has been argued that this is no particular disadvantage, as it only means coming up to the signal under control. Theoretically, this is true, but I will be willing to wager that the engineman who has been fooled several times and lost considerable time by bringing his train under control would say to himself that it is all O. K., and discover his error too late to stop his train in time to avert an accident. The danger lies not so much with the roundel, but with the question of discipline and the willingness to take chances involving a risk.

There are several factors that combine to make a perfect roundel, i. e.,

1st. Quality of glass.
2d. Solid color.
3d. Composition of color.
4th. Thickness of glass.
5th. Finish.
6th. Uniformity.

The quality should be the best lead glass, as it transmits more light than lime glass, and, being harder, it withstands the chemical action of the atmosphere better. The roundel should not be flashed, as such glass is liable to chip and a danger signal taken for a clear. The composition of color should be such as to allow the best impression of red or green at the greatest range.

It is a well-known fact that a white light can be seen at a much greater distance than a colored one, the reason being that a ray of white light is not converted into colored light by passing through a colored medium, but because certain of its component parts are absorbed; besides this, some of the light is reflected—consequently the intensity of the original illumination is greatly reduced. Photometric comparison of the intensity of illumination, passed through red roundels placed before white lenses, gave approximately 23 to 46 per cent. of that passed through white lenses alone; the green roundels gave a somewhat less percentage than the red. This being the case, the composition of the color in the ideal roundel must be such as to allow passage of the greatest percentage of light impregnated with the distinctive color wished. This, to a certain extent, may be accomplished in the red by diluting the spectrum standard with the hue with which it is most closely associated in the spectrum, i. e., orange. Green being nearly in the center of the spectrum, can be diluted at both ends by yellow and blue. The spectro-photometric analysis of the roundels that could be seen at the greatest distance illustrate this fully. The roundel must be of sufficient thickness to withstand the various atmospheric changes and the expansion and contraction of the semaphore spectacle frame. As there is greater reflection, refraction and diffraction of a ray of light, to say nothing of the amount of dust, dirt and snow that will cling to a rough piece of glass, the finish is by no means a small item, also uniformity in saturation of color and thickness is very important, as then each signal will be of equal efficiency.

The lamps, the founts, burners, wicks, and especially the oil used, are of manifest importance. How there can be any economy in using materials of an inferior quality in such an important branch as railway signaling I have been unable as yet to be convinced, for the great object is to lessen the danger to life and property, and even one small accident, due to the misinterpretation of a signal because a road in a spasm of economy has adopted the use of inferior oil or some cheap material in its signal department, will offset the small amount saved as a result of such economy a thousand or several thousand times.

The condensing lenses used in semaphore lamps are a matter of much importance and will be the subject of a future paper.

DISCUSSION.

The President:—I think we would better let the Association discuss that paper. It is really on signals when we need signals most, at night time, and we must depend on colors, so unless there is objection to it, I shall be glad to have the Association discuss it, or ask questions. Dr. Black will be ready to answer questions which may arise in your minds.

Mr. Morrison:—I would like to ask if Dr. Black has made any tests with that new blue white lens that has recently been gotten out.

Dr. Black:—That is what I mean to put into the paper devoted to lenses. I have made some tests, yes.

Mr. Morrison:—They claim to give a white light that is a yellow light through the ordinary plate lens.

Dr. Black:—The blue in the blue white lens, blue being the complementary color of yellow, will cut out the yellow rays of light due to the kerosene flame, consequently it makes a whiter light. But this blue being in the glass, a larger amount is absorbed by the glass of the lens itself, the light going through a white lens taken as 100, compared with that going through a blue white lens, will probably represent anywhere from 90 to 95 per cent. intensity of the illumination going through the white lens, so it is not as efficient a light as a white lens, but on roads using yellow for caution and wish to get rid of the yellow going through the white lens, the blue white lens does away with that principally, and even if the blue white is used and the intensity of the illumination is less than that of the white lens, it can be seen so much farther than the light coming through a red, green or yellow lens; it is a more efficient signal than that coming through any of those colors.

Mr. Morrison:—Dr. Black, is there so much difference in the appearance of the light so that roads using white throughout, the engineer can distinguish the semaphore light easier, or is there a difference between that and some foreign light, such as the lamp on the crossing gate? Could the engineer tell the semaphore light from the light on the crossing gate better by using the blue white lens than the ordinary flint lens?

Dr. Black:—That would depend a great deal on the personality of the engineman. Some eyes can determine the difference in the intensity of an illumination very much better than others and some can distinguish between the small percentage of color in a light very much better than others, and a man who can distinguish the difference between the colors and intensity of illumination between a flint lens and a blue white lens, would be able to distinguish the difference spoken of by yourself so that it is a question of personal equation. The person who has normal color vision would be able to do it very easily at certain distances; at greater distances, or at the entire distance which those lights can be determined, whether he could or not is a question which will have to be worked out.

Mr. Ten Eyck:—Would a blue white lens have any effect on an electric light? Inasmuch as the electric light, I believe, is practically white, devoid of all yellow, or with only a little in it, would that have any effect in choking off the ray, if you use a blue white lens.

Dr. Black:—Do you mean using a blue white lens in front of an incandescent light?

Mr. Ten Eyck:—Yes.

Dr. Black:—You say there is no yellow in it?

Mr. Ten Eyck:—Not as much as in kerosene.

Dr. Black:—Well, it would have the effect of making the light more nearly a pure white illumination, as it would cut off the yellow rays.

Mr. Ten Eyck:—Practically the same as it would with an oil light.

Dr. Black:—Yes, it will cut off whatever rays of yellow emanate from the source of illumination, in proportion to the amount of blue it has in its make-up.

Mr. Ten Eyck:—Well, would the blue in the make-up have any effect on pure white light?

Dr. Black:—It is hard to obtain pure white light.

Mr. Ten Eyck:—I mean theoretically.

Dr. Black:—Theoretically, it would diminish the intensity of the illumination only a small percentage; practically it would not diminish the efficiency of the light.

DISCUSSION ON DR. BLACK'S PAPER.

BY MR. A. G. WILSON, ENGINEER OF TESTS, UNION SWITCH & SIGNAL CO.

For the same reason given by Dr. Black, "the noticeable difference in intensity of illumination of colored signals, etc.," we began, about three years ago, to make regular photometric tests of signal glass, with a view to the adoption of standards of comparison, and allowing a fixed plus or minus variation in amount of light transmitted as compared to selected standards.

To arrive at suitable standards for railway use, we suggested that the proper railway officials select from an assortment of glass a maximum and minimum as to amount of light transmitted, and subject them to a track test similar to that given by Dr. Black. The selected pieces proving satisfactory, we then have standards for comparison in making photometric tests.

Any glass of the same color having a photometric value not greater than the maximum nor less than the minimum should upon night

test be found visible within the ranges given for the maximum and minimum.

The Atchison, Topeka & Santa Fe having already adopted photometric tests for signal glass, we procured from them duplicates of their approved standards. These, together with some samples submitted by other roads as being a satisfactory maximum and minimum, have been useful in arriving at satisfactory results.

In reply to Dr. Black's request for samples of colored glass, it is probable that he received but one piece from each firm. His photometric test shows that the variation in amount of light transmitted is 77 per cent. for the red glass and 51 per cent. for the green.

Our past experience has taught us that if we were to place an order for 500 semaphore glasses, without some specification as to the amount, maximum and minimum, of light to be transmitted when compared to a selected standard, we can expect a much greater variation than was obtained in the test of the samples by Dr. Black.

Had the glass used in the track test been of equal photometric value, there might have been some other interesting features developed. Of course, if a certain glass transmits 50 per cent. or 70 per cent. more light than another, it is expected that the most light will be visible the greatest distance.

As to whether the colored light that can be seen the greatest distance is the best for a railway signal, it is a question that is not generally agreed on.

It has not been uncommon to hear a red criticised as being too pale, or a green as being too yellow or too blue. Against this we have a piece of glass sent us as being a satisfactory green for one road. Upon spectroscopic test we find that it absorbs but slightly of any of the colors except red.

While the above statement may convey some idea as to the difference of opinion as to what constitutes a good green, it may also be interesting to note that from a single shipment of green glass received, at least six different shades were to be found, showing that manufacturers were not fully able to control their mixture or that they were careless.

The spectroscope is found quite helpful in connection with photometric tests By its use we have found that, of different makes of red glass of equal photometric value, one make may have complete absorption for yellow light and the other will absorb considerable of the red and transmit some of the yellow. A further search will reveal the fact that when a glass of one make is obtained that will not transmit yellow it is so dense that it will not transmit enough light, while with the first piece of glass, found impervious to yellow, we can select pieces of higher photometric value when more orange is transmitted, proceeding by steps until arriving at a point where yellow begins to appear in the spectrum.

The production of a satisfactory red glass is therefore a comparatively simple matter, as the red can be diluted with the orange as desired.

The green being capable of dilution by the addition of blue or yellow, naturally becomes more complex.

Our first experience with yellow glass showed that there was not much difference between an oil lamp without any glass and an oil lamp with yellow glass in front of it.

An examination of several specimens of yellow glass proved that it absorbed but little of any of the colors except part of the blue. Experiment has shown, however, that a yellow can be produced which will absorb slightly of the red, most of the green, and all of the blue.

Take a glass of the above description and place it in signals along with red glass transmitting yellow and there will probably be some chances for error.

Therefore, to avoid error, it would seem equally important that the red glass should be of a pure, unmistakable color.

Referring to the spectro-photometric test of Macbeth and Kopp green, we find the results about equal except on the "G" line. Checking the total of this test with the photometric test we find that they agree. However, the bi-concave lens test indicates that the light from the Kopp green would be visible 98 per cent. of the distance that the light from the Macbeth green is visible, while in the track test Kopp green was visible but 81 per cent. of the distance that Macbeth green was visible.

Let us take the distance at which Corning green was visible and give that a value of 100 per cent. and compare the distances at which the different greens were visible, with the bi-concave lens test, when we have

GREENS.

	TRACK TEST.	BI-CONCAVE LENS TEST.
Corning	100 per cent.	100 per cent.
Sneath	85 per cent.	98.2 per cent.
Baird	58 per cent.	69.4 per cent.
Macbeth	80 per cent.	67.0 per cent.
Kopp	65 per cent.	66.0 per cent.

Since the distance at which Corning red was visible could not be obtained, let us take the track and bi-concave lens test of Kopp red, assign to it a value of 100 per cent. and compare with Baird red.

REDS.

	TRACK TEST.	BICONCAVE LENS TEST.
Kopp	100 per cent.	100 per cent.
Baird	87 per cent.	73 per cent.

These comparisons show some variations that have not been explained. Since it was raining at the beginning of track test and clear before it was completed, atmospheric conditions may have had some influence on the results.

There is no question about the six factors named being required to make a perfect roundel.

We have been using lead glass from the beginning. It not only transmits more light, but is more susceptible to the influence of the coloring matters.

MR. BLACK'S REPLY TO MR. WILSON'S DISCUSSION OF COMPARATIVE TESTS OF ROUNDELS.

The method referred to by Mr. Wilson to obtain roundels satisfactory to the railroads is excellent; that is, by having them select from an assortment of glass a maximum and minimum as to amount of light transmitted, and then when subjected to a track test and proving satisfactory, use them for standards for that particular road. The only trouble is that each road will have a different standard, and in the majority of cases, not having a photometer, will compare their stock by holding them between the eye and a source of illumination and try to select roundels between the maximum and minimum standards. This is an utter impossibility for several reasons: First, the eye cannot distinguish between quite marked differences in degree of luminosity when transmitted through a colored medium in the manner described—it requires an instrument like the photometer.

Secondly, the eye becomes too fatigued in a short time and the error referred to above is much increased.

Thirdly, the eye cannot distinguish between glass whose color is made up of the proper mixture of spectrum colors to give the best efficiency and those not, without a spectroscope.

If Signal Engineers could be supplied with a photometer, as the A., T. & S. F. R. R. has done (this is what it must come to unless done by the firm supplying the glass), then the standard adopted by the road could be maintained. But what we want is to have all roads adopt and use a uniform standard and have that a glass of "par excellence."

The comparative tests of different makes of glass having equal photometric value would indeed be interesting, and I hope to carry out same at a future time.

In writing for samples the use they were to be put to was definitely stated, and I naturally hoped to obtain as good a product as was made by each firm, but letters received later state that such was not the case.

The statement that reds are too pale, or greens too yellow or blue, is the point on which all color signal work hinges, and depends entirely on the chromatic sense of the individual—one may be defective in red color sensation and will find a red too pale, that gives to the person with normal chromatic sense a perfect color and has spectroscopically the largest percentage of red in its make-up, but because of his defect the density of saturation is not sufficient to give him the impression of a perfect red. The same with one defective in green sensation.

We must have a standard to go by—consequently what has been accepted as the average normal color sense must be taken as the standard.

My understanding has been that it is easier to produce a good green solid color than a red, as the dilution of the green can be effected by the addition of yellow, orange, and even red towards one end and blue and violet towards the other.

I thoroughly agree with Mr. Wilson regarding the yellow, that in order to be efficient it must have so much orange and red in its composition that it is liable to be mistaken for a red light, especially by one whose color sense is not acute or where some atmospheric media diminishes the intensity of the illumination and color.

The variation in the bi-concave lens and track test, as noted by Mr. Wilson, was observed, and no satisfactory explanation could be arrived at. In the lens test the lamps were only 10 meters or less distant, in a perfectly dark room, the effect of distance being produced by the bi-concave lenses; while with the track test there was from 1½ to 3 miles of atmosphere intervening, varying from a hard rain-storm to bright moonlight, which may account for the difference.

I am very much pleased with the fairness, and not a little flattered by the kindly way Mr. Wilson has treated my efforts, it being the farthest from my intention to run down any one make of glass or praise another; simply to find out facts and help to establish a standard in uniformity and excellence in signaling.

BY GEO. A. MACBETH,

PRESIDENT MACBETH-EVANS GLASS COMPANY.

We have received your copy of tests of roundels, and wish we had known something about it, for we would not have sent you the character of glass which we did, as those sent are meant for and are used in automobile lamps which provide for abundance of illumination. You do not give the diameters of these glasses tried, but very properly give the thickness. Also, there is an omission of statement whether Corning samples were flashed or not, also whether any of the glasses were polished or not. Those we sent you were not polished. This would make quite a difference in the amount of rays transmitted. There is also all the difference in the world in the depth of color. We have considered the main requisite of a lens or a roundel, that it must be made, not only of lead glass, but of a first-class lead glass. There are only two in the list you send who claim to make the lead glass at all.

There are some things in these colors for which railway men are to blame. The first is, the demand very often for deep red—the deeper the red more loss of light. Then, in the case of the green, it has been so that anybody has had his "pull and say," in regard to what he considered green, judging them by daylight. So we have seen greens

which looked green enough by daylight and which would show up twice as much light through them, but at night when placed on lamp look gray at 600 or 800 feet. We have carefully avoided the gray appearance and have been scolded for furnishing what we call a "peacock" green of light shade. The very best shade has been returned and darker shade demanded. The idea has prevailed that the lens made light in some sort of way. So our efforts have been confined to making unmistakable red and green which would certainly show within stopping distance and could not be mistaken by a man with ordinary color vision for anything else—the green to show a bright emerald green. If you had taken plain sheet glass of red and green, such as is sold in the market, you could have shown the transmission of different rays which would have been better than anything that we could make, yet this glass is of such a flimsy character that we do not consider it at all safe for signals. We believe we were the first to furnish a strong, stout lead glass in roundels ¼-inch thick, which was sure not to break, and which so far for twenty-five years has been entirely successful. As most of them are put in work where they are allowed to become covered with soot, and very often half-painted over, we did not consider it worth while to polish the glass. Some of them used on railways look as if they had never been cleaned in any manner whatever. As for the yellow, we leave that to the railway men to say what they want—we agree with what you say.

The flashed glasses will certainly transmit more light, but those interested in making a solid color have succeeded in making demand for solid. We have never found any trouble to come from flashed glass. We cannot agree with you that flint glass transmits more light than the lime glass—all reports from optical people state the opposite—if there is any difference. There is no particular difficulty in making a solid ruby lens of 4 or 5 inches' diameter, but the chemicals necessary to use are incompatible with a good lead glass. The color looks "pretty" enough, but we do not like to recommend to a railway company the placing of a thick glass like this in a hot lamp with the outside exposure to cold winds made of lime glass, for it is liable to crack and break.

We wish to avoid the personality involved in a thing of the kind, and suppose if we did not wish our glass tested we should not have sent any, but we could not be satisfied with the matter without examination of what has been tested. It is a big job to go through a test of the kind, and how you did so with the couple of glasses sent you on such a late date and short time occupied is beyond us.

We have hardly time to examine into the merits of the showing of the location of Fraunhoefer lines, but at first glance are somewhat puzzled at the showing of the green; for instance, in the "b" line you put us down as 14.9, while the Sunlight you mention as 14.1.

MR. BLACK'S REPLY TO MR. MACBETH'S CRITICISM.

In reply to your favor of the 31st ultimo, would state that my first letter to you, requesting samples, stated what I desired to use them for, although I did not state diameter of roundel wished.

All the samples received were solid colors, with the exception of the red sent by Sneath Glass Company, which was flashed. None of the samples had any high degree of polish—surface was simply smooth.

I entirely agree with you that the men who select the roundels for the various roads are, in the majority of cases, to be blamed for the difference in depth of color, they simply accepting what pleases their individual eye, and it is a well-known fact that to no two persons do colors appear the same. Then again, their methods of selecting have a maximum and a minimum standard of depth of color, and any roundel appearing to come between this maximum and minimum intensity is accepted. After four or five minutes' work of this kind the color-perceiving apparatus of the eye becomes so fatigued that very great degrees of intensity of color cannot be differentiated. Again, in pieces of glass having to the eye apparently the same depth of color, one will transmit a very much larger percentage of light than the other.

It is perfectly true that roundels are placed in positions where they become covered with soot and smoke, but nevertheless the finished article placed in such a position should be the best, no matter what its after environment may be. A great deal more soot, dirt, etc., will cling to a rough surface than to a polished one.

Wherever the term "flint" glass appears in the paper, it is meant that a clear glass lens was used and transmitted white light, flint not intended to designate the quality of glass.

Your reference to placing a thick glass like these in a hot lamp with the outside exposure to cold winds I do not understand, as roundels do not come in contact with the heat of the lamp.

You state you would not be satisfied with the matter without examination of what has been tested. I have the roundels in my possession and same are at your disposal should you care to use them in making same tests as I did. It certainly is no small job to go through tests of this kind. The red lens of your set of samples was the only one of that set put through the test. I had previously obtained two Macbeth green roundels from the C., M. & St. P. stock-room, and the one giving the best results in a distance test was put through the tests described in the paper.

The number 14.1 to which you refer is simply the location on the mitered scale of the spectroscope used of the "b" line, and has absolutely nothing to do with the transmission of illumination.